TM 213

OZONE COMPENSATED MONOBEAM PNEUMATIC DETECTOR

DA 18-035-AMC-314(A)

FINAL REPORT

Prepared for:

Commander
U. S. Army Chemical Research
and Development Laboratories
Edgewood Arsenal, Maryland 21010

Attention: Mr. David L. Tanenbaum, Project Officer

Beckman® INSTRUMENTS, INC.
ADVANCED TECHNOLOGY OPERATIONS
FULLERTON, CALIFORNIA • 92634

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CONTRACT NO. DA 18-035-AMC-314(A)

TO: Commander
U. S. Army Chemical Research
and Development Laboratories
Edgewood Arsenal, Maryland 21010
Attention: Mr. David L. Tanenbaum, Project Officer

FROM: Beckman Instruments, Inc.
Special Projects Division
2400 Harbor Boulevard
Fullerton, California 92634

Approved: Taylor C. Fletcher

ABSTRACT

A three section Monobeam Pneumatic Detector has been designed and fabricated. The gas charges employed in this detector have been selected to allow nearly complete cancellation of response to ozone. The mechanical design provides a factor of 75 improvement in signal to microphonic noise ratio compared to previous Monobeam detectors. Measurement of response and noise characteristics by the U. S. Naval Ordnance Laboratory indicates a $P_{N\,mm}$ of 8.5×10^{-10} watts/cps$^{\frac{1}{2}}$ at the peak wavelength of 9.8 microns.

Description

The detector is constructed with three series-optical pneumatic cells in a Monobeam configuration. In the cells, the back volumes are located to balance out the differential forces which normally exist between the diaphragms and the fixed electrodes when the detector is subjected to acceleration forces. A sectional view of the front cell is shown in Figure 1.

The three cell unit has the dimensions 2.0" h x 1.8" w x 3.7" l. The aperture is 0.375" in diameter.

The detector is normally charged as follows:

D_1 = 200 mm/15% SiF_4 in Argon*
D_2 = 200 mm/10% $CF_2 = CFCl$ in Argon
D_3 = 200 mm/15% CCl_2F_2 in Argon

Discussion

The microphonic characteristics of this detector were tested and compared with those of a noncompensated LOPAIR pneumatic Monobeam Infrared Detector. The new design exhibited an improvement in signal to microphonic noise ratio (Figure of Merit) of 75:1 over the previous design, as illustrated in Table 1. Figures of merit for nonmicrophonic detectors are discussed in the following section. Comparison of figures of merit between these designs as a function of vibration frequency is shown in Figure 2. Output signal as a function of vibration frequency is shown in Figure 3.

* Depending on the results of ozone compensation and LOPAIR system measurement tests, D_1 may be charged with CF_2CFCl and D_2 with SiF_4.

Performance

Two measures of the nonmicrophonic performance of a pneumatic detector are given below. A "figure of merit" is defined which directly compares the nonmicrophonic performance between any two detectors. An "alternate figure of merit" is defined which is easier to measure, and, while it is useful, may give somewhat different results for different detector designs.

"Figure of Merit"

The basic criterion for the nonmicrophonic characteristic of a detector is the signal to noise ratio, where the noise is defined as that which is due to vibration. A "figure of merit" which expresses this signal to noise ratio is:

$$\text{Figure of Merit} = \frac{\dfrac{\text{output signal}}{\text{radiant power}}}{\dfrac{\text{output signal}}{\text{acceleration}}} = \frac{\text{acceleration (gravity units)}}{\text{radiant power (watts)}}$$

"Alternate Figure of Merit"

The inverse of the force required to maintain the detector diaphragm in its original position, when the detector is subjected to an acceleration, is a measure of the nonmicrophonic quality of a detector. A voltage between the diaphragm and the detector button will provide such a force, thus, we can define the "alternate figure of merit" as:

$$\begin{array}{c}\text{Alternate}\\ \text{Figure of Merit}\end{array} = \frac{\dfrac{\text{output signal}}{\text{bias voltage change}}}{\dfrac{\text{output signal}}{\text{acceleration}}} = \frac{\text{acceleration (gravity units)}}{\text{bias voltage change (volts)}}$$

This criteria is not quite as fundamental as the "figure of merit", however, it provides a useful second check on the detector design.

The various measurements tabulated in Table 1 were measured as follows:

1. Output signal was measured using Beckman Mark IV Radiant power source #750. This source was modulated at 2 c/s.
2. Output signal due to vibration was determined by a sinusoidal displacement of 3/8" peak to peak over a range of frequencies. Calculations were performed at 2 c.p.s. Higher frequencies show an additional improvement which is approximately linear with frequency.
3. To determine the voltage required to develop a force on the diaphragm equivalent to that developed by the acceleration, an audio voltage is applied directly between the diaphragm and the stationary electrode. The output signal for a given peak to peak audio voltage (bias voltage change) is measured.

Both the "figure of merit" and the "alternate figure of merit" improve approximately linearly with the frequency of vibration.

Testing

The attached appendix is a copy of test results obtained on D_1 (SiF_4 charged) of a three-section nonmicrophonic Monobeam Infrared Detector at the U. S. Naval Ordnance Laboratory, Corona, California. The measurements were performed with the detector equipped with a recently developed solid state oscillator-demodulator unit. This preamplifier results in an approximately 33 percent improvement in signal to noise, based on NEP measurements at 2 c/s, compared to the same detector with the best vacuum tube oscillator-demodulator.

The solid-state preamplifier, occupying a space of 1 x 1 x 3", incorporates three low noise transistors and a metal-silicon hot carrier diode as shown in the circuit diagram, Figure 4.

	Output signal / Radiant power (RMS volts/watt)	Output signal due to vibration (Volts)	Output signal per gravity unit (Volts/g.)	Output signal / Bias vltg. change (Volts/volts)	Figure of Merit (g./Watts)	Alternate Figure of Merit (g./volts)
D-2 of four cell Monobeam LOPAIR detector	$0.83/K_1$	1.6×10^{-2}	1.05×10^{-1}	0.13	$7.9/K_1$	1.24
D-1 of three cell nonmicrophonic LOPAIR detector	$3.25/K_1$	8.5×10^{-4}	5.5×10^{-3}	0.56	$590/K_1$	102
Ratio of improvement of nonmicrophonic design over previous design	3.9	19	19	4.3	75:1	82:1

All data at 2 cps
D-2 of four cell detector and D-1 of three cell nonmicrophonic detector contain 200 mm hg 10 percent CF_2 = CFCl in argon, with wavelengths below 8μ cut off by a long pass filter.
Vibration displacement = 0.375" peak to peak.
Acceleration (p-p) = 1.53×10^{-1} gravity units @ 2 cps.
Voltages are peak to peak except as otherwise noted.
Oscillator R. F. voltage = 20 V/25 V peak.

TABLE I

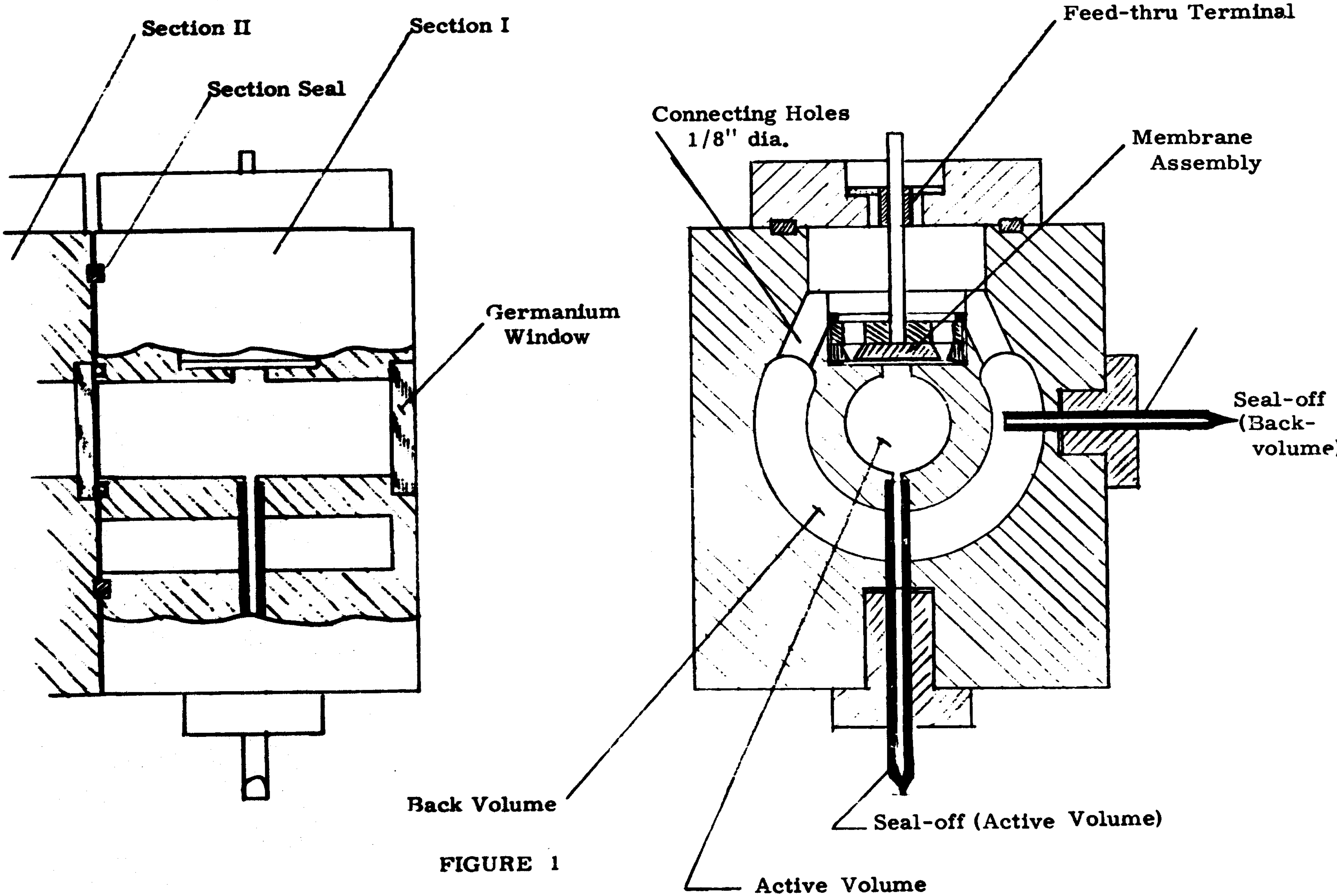


FIGURE 1

NON MICROPHONIC – MONOBEAM – PNEUMATIC DETECTOR

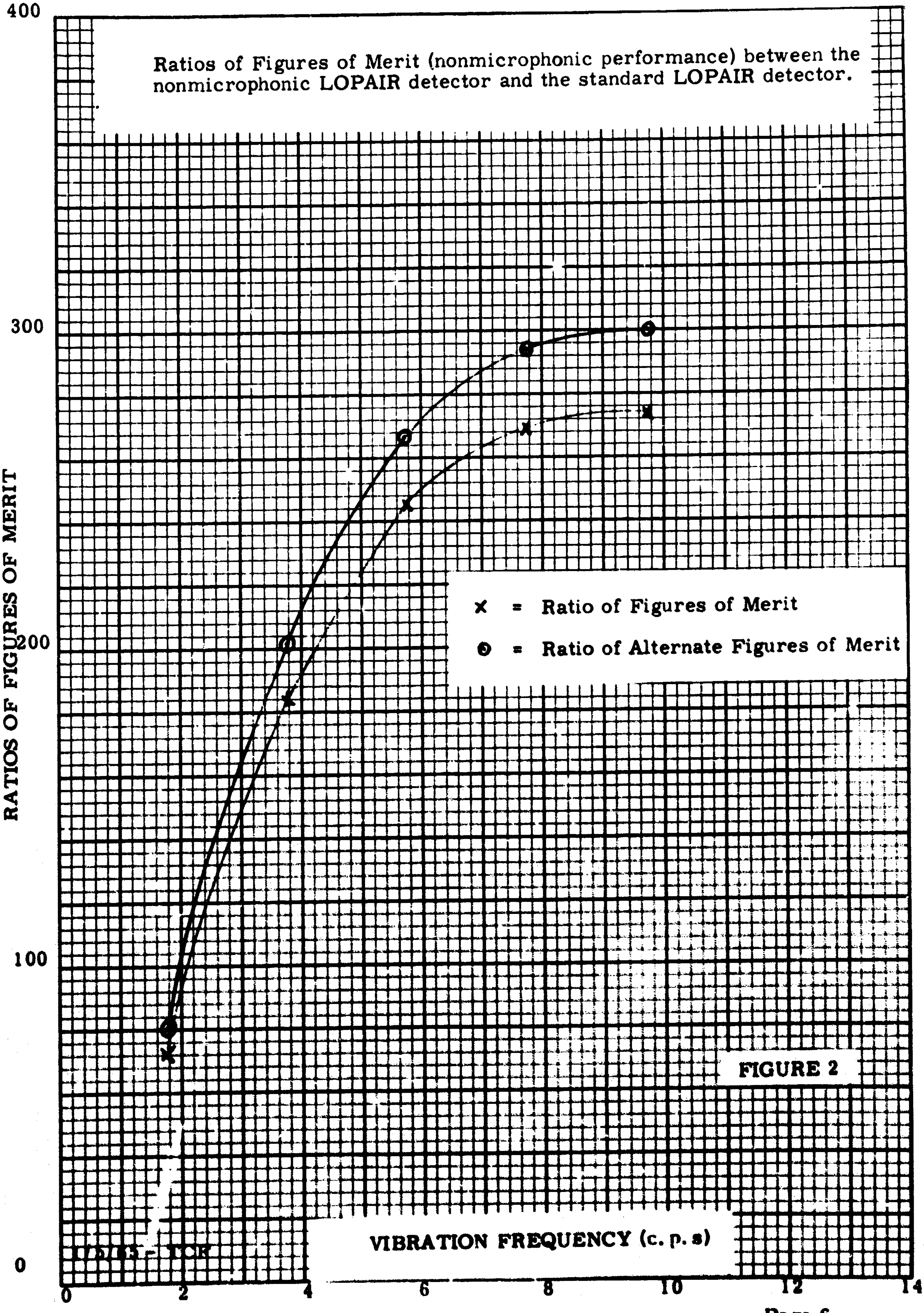

Ratios of Figures of Merit (nonmicrophonic performance) between the nonmicrophonic LOPAIR detector and the standard LOPAIR detector.
× = Ratio of Figures of Merit
⊙ = Ratio of Alternate Figures of Merit
RATIOS OF FIGURES OF MERIT
VIBRATION FREQUENCY (c. p. s)
400
300
200
100
0
0
2
4
6
8
10
12
14

FIGURE 2

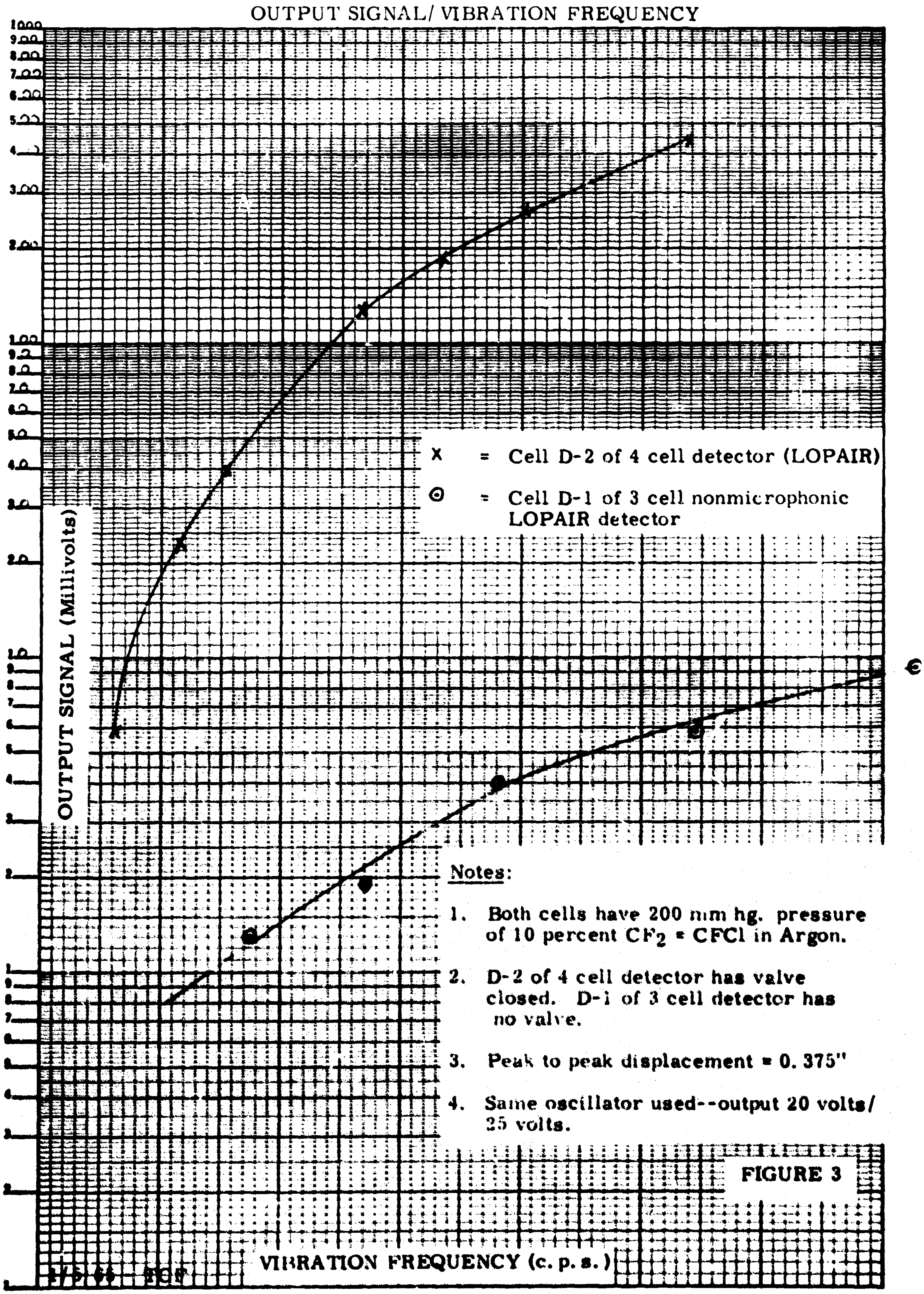
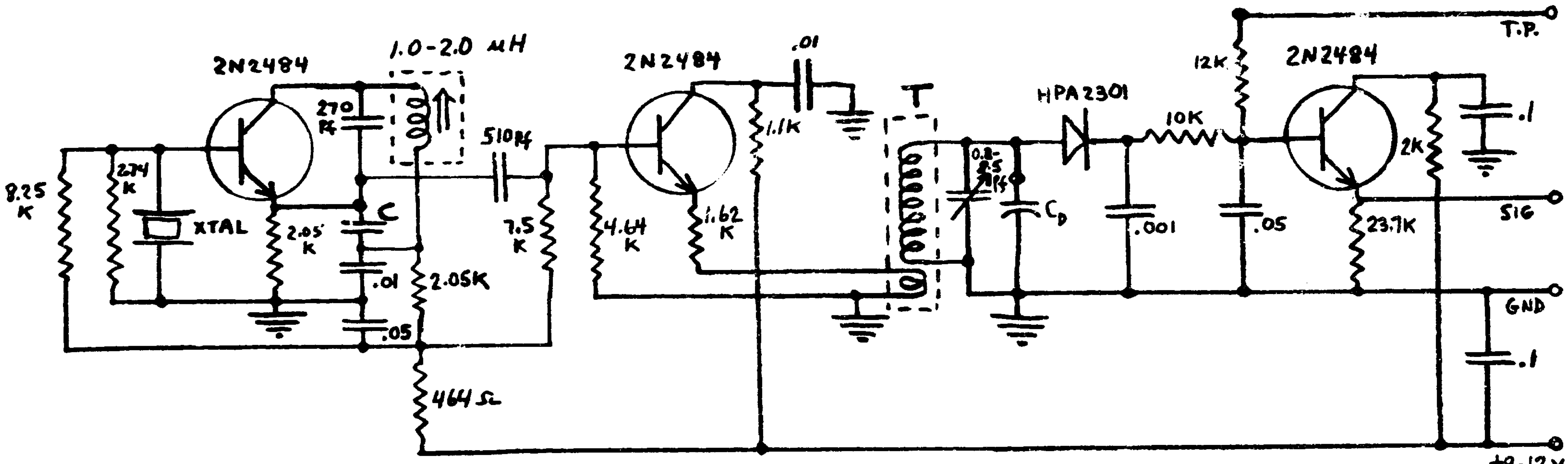

OUTPUT SIGNAL/ VIBRATION FREQUENCY
OUTPUT SIGNAL (Millivolts)
VIBRATION FREQUENCY (c. p. s.)
X = Cell D-2 of 4 cell detector (LOPAIR)
⊙ = Cell D-1 of 3 cell nonmicrophonic LOPAIR detector
Notes:
1. Both cells have 200 mm hg. pressure of 10 percent CF2 = CFCl in Argon.
2. D-2 of 4 cell detector has valve closed. D-1 of 3 cell detector has no valve.
3. Peak to peak displacement = 0. 375"
4. Same oscillator used--output 20 volts/ 25 volts.

FIGURE 3



All resistors metal film Type

XTAL	C pF	T
9.5 Mc	510	PRI. 3T. Sec. 57T #32 HPU on Micrometals T 44-2 Toroid $L \approx 18 \mu H$ $Q \approx 95$
10.7 Mc	510	PRI. 3T. " " " " " " " "
11.9 Mc	330	PRI 3T. Sec 52T #30 Teflon on Micrometals T 44-6 Toroid $L \approx 12.5 \mu H$ "

Lopair Oscillator - Demodulator Unit (one section)

CHB 6/29/65

APPENDIX

U. S. NAVAL ORDNANCE LABORATORY
CORONA, CALIFORNIA 91720

JUN 28 1965

IN REPLY REFER TO

431:WLE:ms
3900
4393
25 June 1965

Mr. Taylor C. Fletcher
Beckman Instruments Inc.
2400 Harbor Blvd.
Fullerton, California

Dear Mr. Fletcher:

Enclosed are copies of the data we obtained on your pneumatic detector. Any questions you may have concerning the data will receive my prompt attention.

The data will be published in a future NOLC "Photodetector Report".

Sincerely,

W. L. Eisenman

W. L. EISENMAN
Head, Detector Branch
Infrared Division
Code 431

Encl:
Data Sheets & Graphs

TEST RESULTS*	
R (volts/watt) (500, 10)	4.8×10^{1}
H_N (watts/cps$^{\frac{1}{2}}$.cm^2) (500, 10)	5.8×10^{-8}
P_N (watts/cps$^{\frac{1}{2}}$) (500, 10)	4.1×10^{-8}
D* (cm·cps$^{\frac{1}{2}}$/watt) (500, 10)	(2.1×10^{7})
Responsive time constant (μsec)	2×10^{4}
$\frac{R_{\lambda max}}{R_{bb}}$	46
Peak wavelength (μ)	9.8
Peak detective modulation frequency (cps)	7
$P_{N_{mm}}$ (watts/cps$^{\frac{1}{2}}$)	8.5×10^{-10}

CONDITIONS OF MEASUREMENT	
Blackbody temperature (°K)	500
Blackbody flux density (μwatts/cm^2, rms)	9.0
Chopping frequency (cps)	10
Noise bandwidth (cps)	0.3
Cell temperature (°K)	296
Cell current for 10 cps data (μa)	---
Cell current for D^*_{mm} (μa)	---
Load resistance (ohms)	(*See note)
Transformer	---
Relative humidity (%)	---
Responsive plane (from window)	---
Ambient temperature (°C)	23
Ambient radiation on detector	296°K only

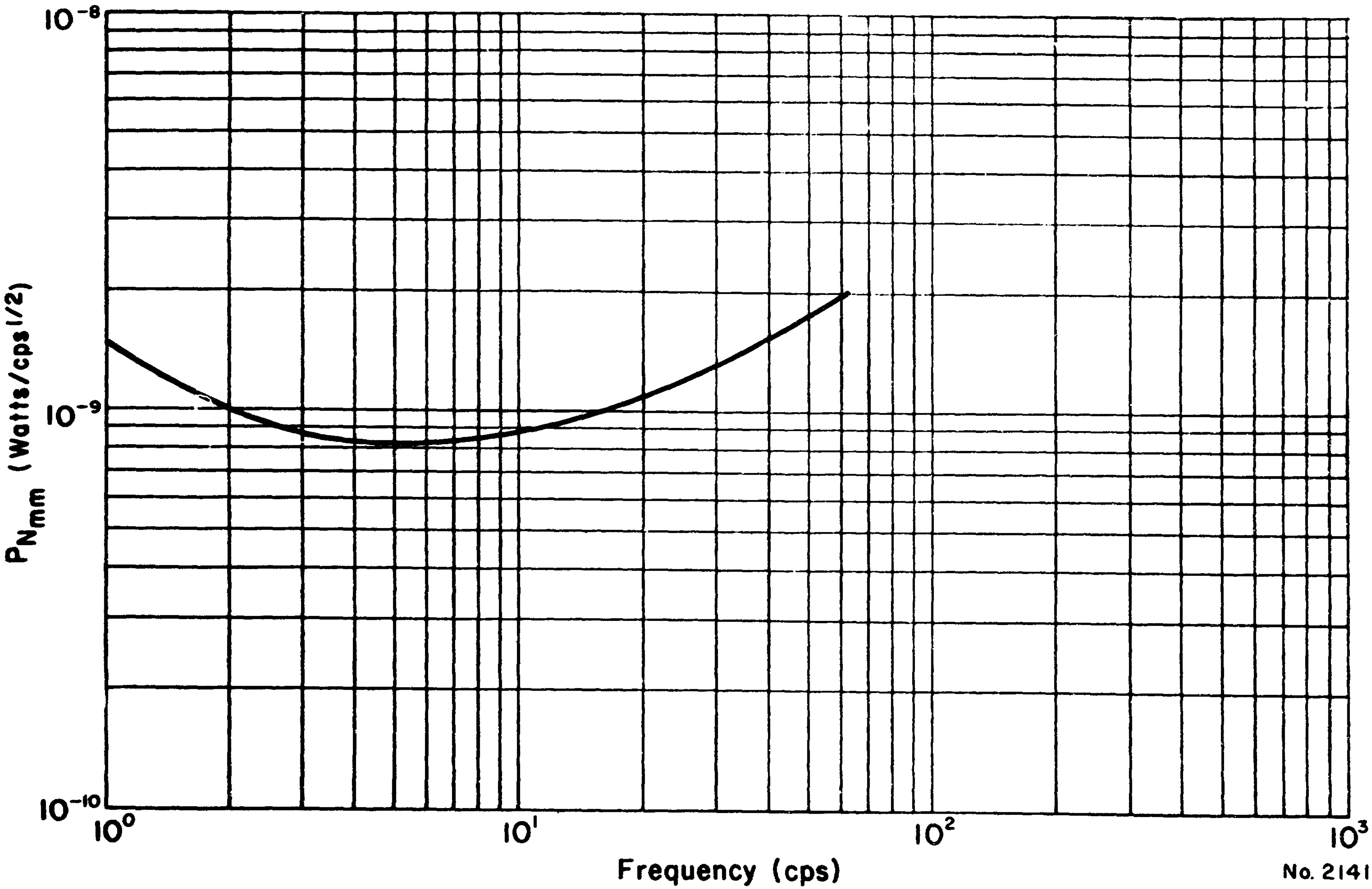
*Detector equipped with internal solid state preamp.

CELL DESCRIPTION	
Type	Pneumatic
Shape of sensitive area (cm)	0.95 dia.
Area (cm^2)	7.1×10^{-1}
Dark resistance (ohms)	(*See note)
Dynamic resistance (ohms)	---
Field of view	---
Window material	Ge

DATA SHEET NO. ______

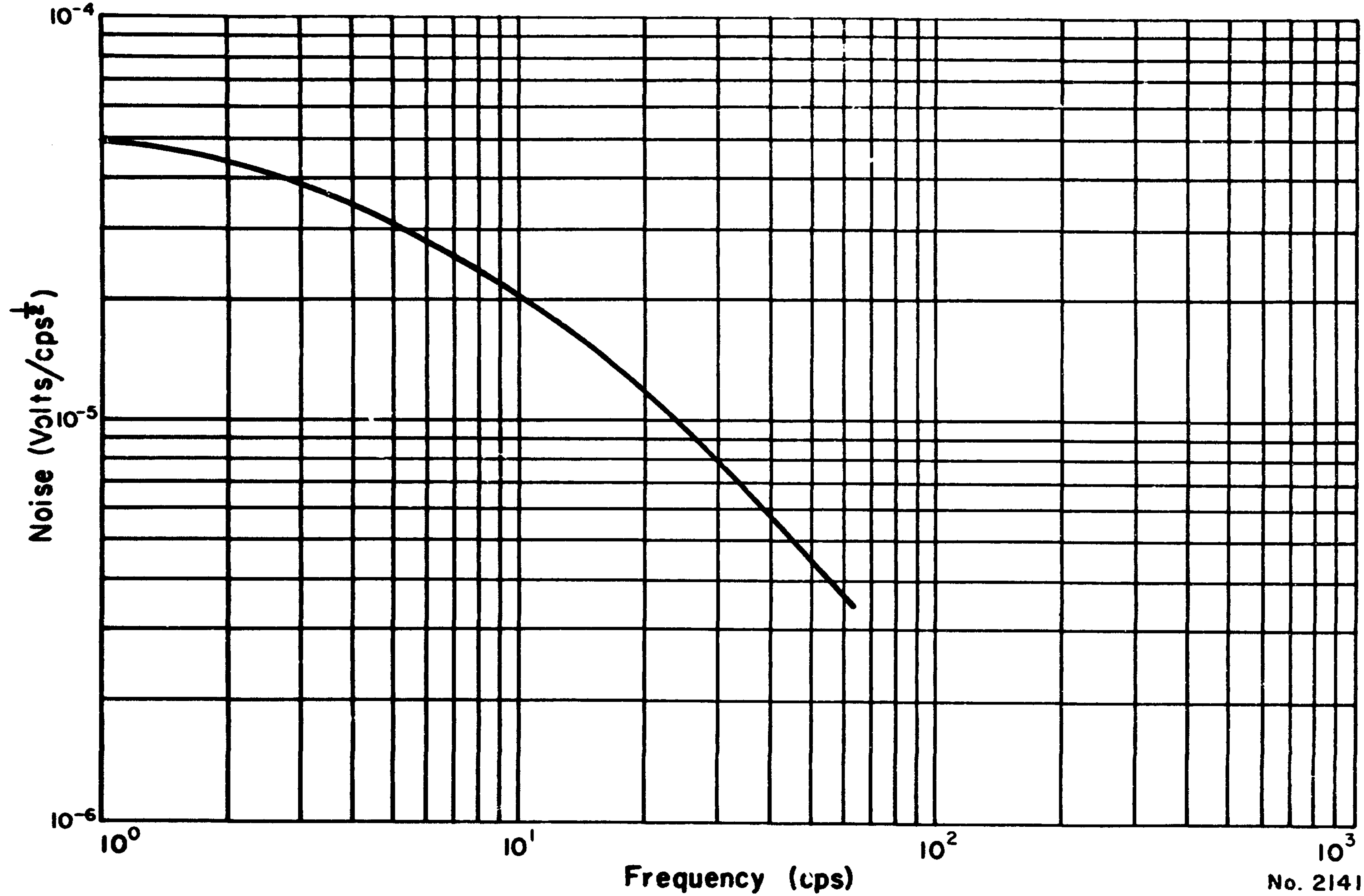
NOLC NO. 2141

DATE 6/21/65

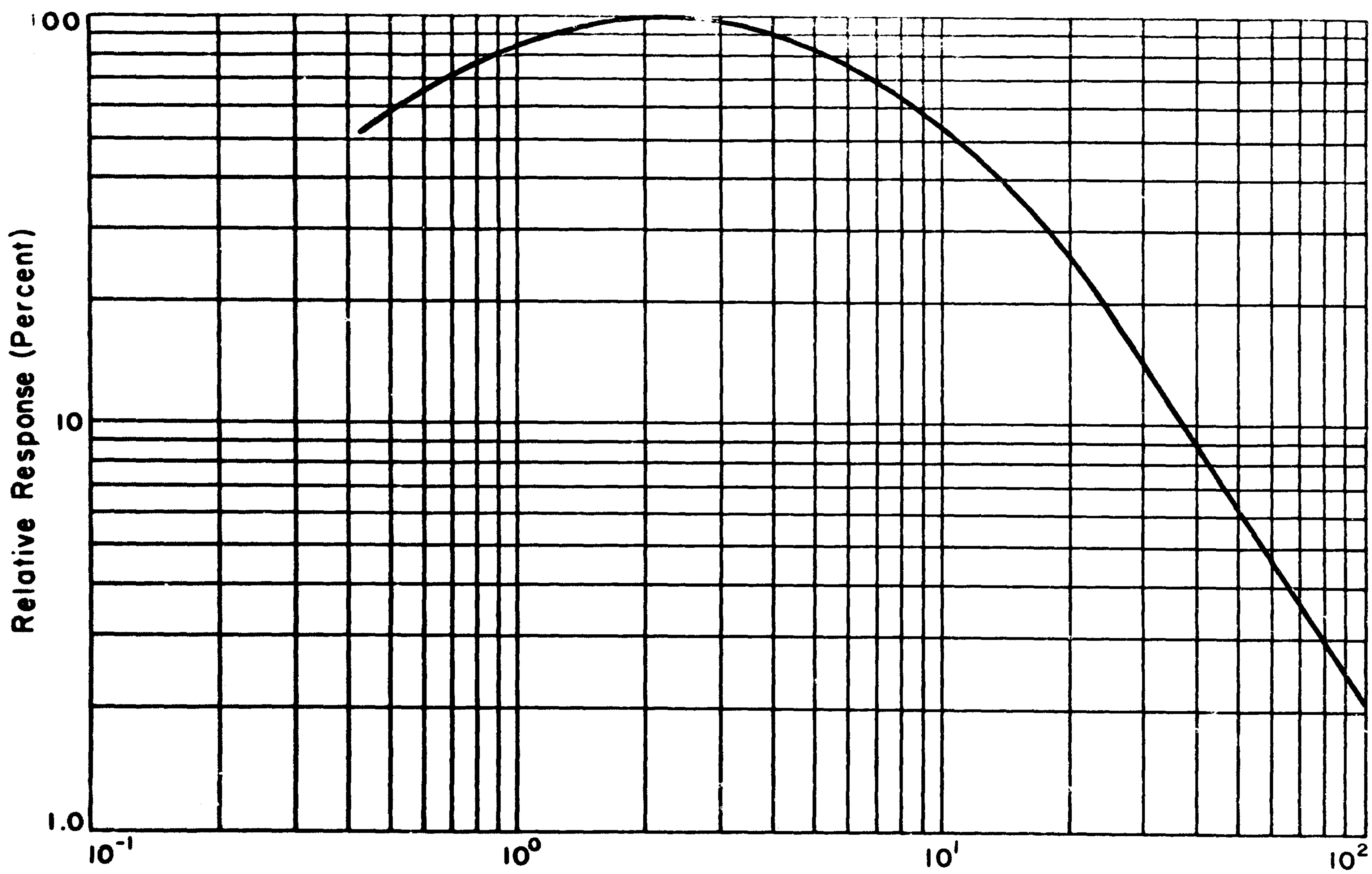


No. 2141

$P_{N_{mm}}$ VS FREQUENCY

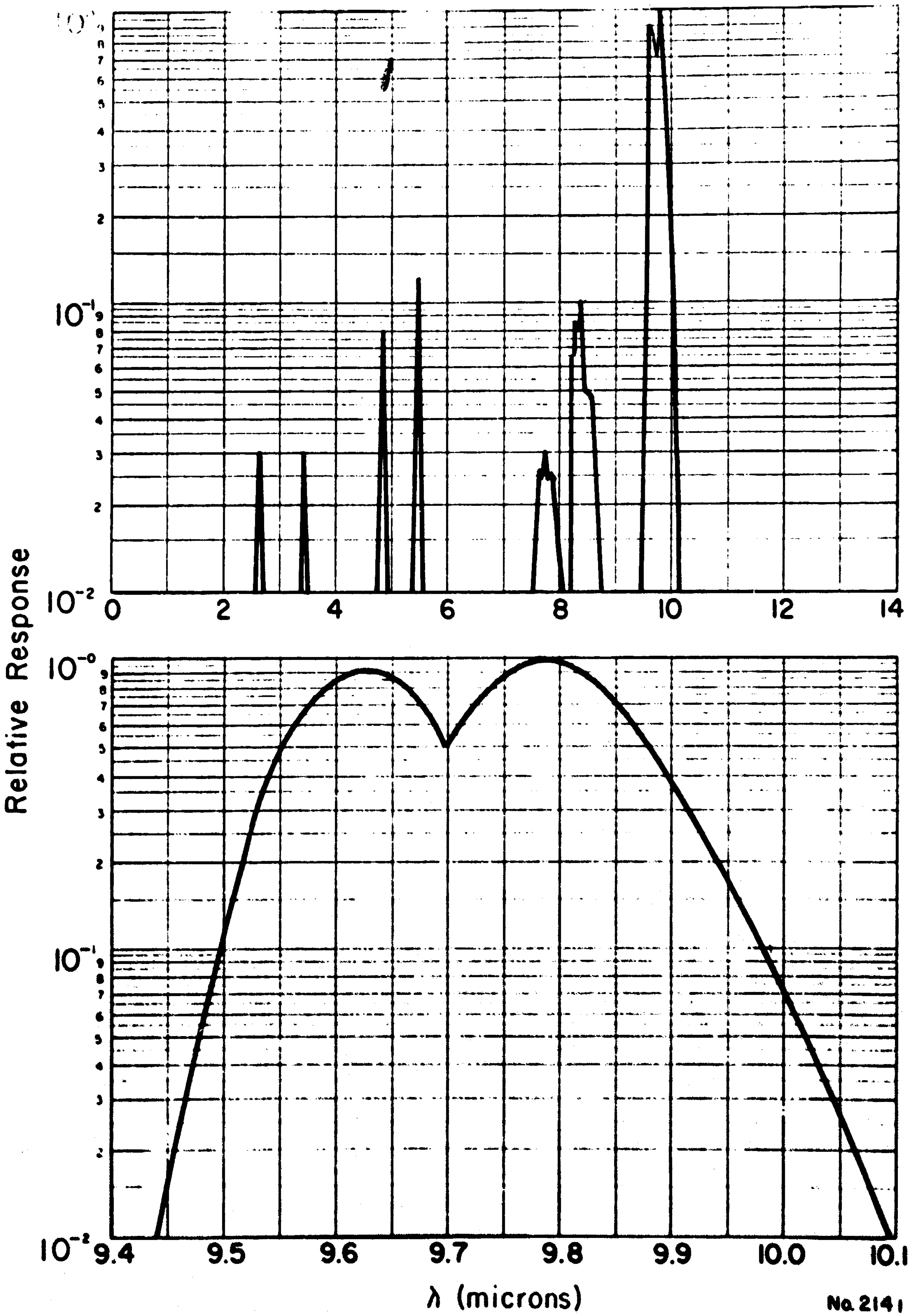


NOISE SPECTRUM



FREQUENCY RESPONSE

No. 2141



SPECTRAL RESPONSE